PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

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NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(PCT Rule 71.1)

	Date of mailing *(day/month/year)* 31.10.2005	
Applicant's or agent's file reference 85/TY00M11/WO	**IMPORTANT NOTIFICATION**	
International application No. PCT/IB2004/002385	International filing date *(day/month/year)* 26.07.2004	Priority date *(day/month/year)* 29.07.2003
Applicant TOYOTA JIDOSHA KABUSHIKI KAISHA et al.		

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary report on patentability and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary report on patentability. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

The applicant's attention is drawn to Article 33(5), which provides that the criteria of novelty, inventive step and industrial applicability described in Article 33(2) to (4) merely serve the purposes of international preliminary examination and that "any Contracting State may apply additional or different criteria for the purposes of deciding whether, in that State, the claimed inventions is patentable or not" (see also Article 27(5)). Such additional criteria may relate, for example, to exemptions from patentability, requirements for enabling disclosure, clarity and support for the claims.

Name and mailing address of the international preliminary examining authority:	Authorized Officer
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PATENT COOPERATION TREATY

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 85/TY00M11/WO	**FOR FURTHER ACTION** See Form PCT/IPEA/416	
International application No. PCT/IB2004/002385	International filing date *(day/month/year)* 26.07.2004	Priority date *(day/month/year)* 29.07.2003
International Patent Classification (IPC) or national classification and IPC G01R31/36		
Applicant TOYOTA JIDOSHA KABUSHIKI KAISHA et al.		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 5 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 11 sheets, as follows:
      - ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

   - ☒ Box No. I Basis of the opinion
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☐ Box No. VI Certain documents cited
   - ☐ Box No. VII Certain defects in the international application
   - ☐ Box No. VIII Certain observations on the international application

Date of submission of the demand 21.03.2005	Date of completion of this report 31.10.2005
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Mapp, G Telephone No. +49 89 2399-6057

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/IB2004/002385

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1-3, 5-14	as originally filed
4, 4a, 4b	received on 21.03.2005 with letter of 18.03.2005

Claims, Numbers

1-18	filed with telefax on 13.10.2005

Drawings, Sheets

1/7-7/7	as originally filed

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-18
	No:	Claims	None
Inventive step (IS)	Yes:	Claims	1-18
	No:	Claims	None
Industrial applicability (IA)	Yes:	Claims	1-18
	No:	Claims	None

2. Citations and explanations (Rule 70.7):

see separate sheet

Re Item V

1. Cited Document

   Reference is made to the following document:

   D1: EP-A-0 909 001 (TOYOTA MOTOR CO LTD ; DENSO CORP (JP); MATSUSHITA ELECTRIC IND CO LTD) 14 April 1999 (1999-04-14)

2. Subject Matter of Claims 1, 9 and 17

   These independent claims disclose a system and method for the control of charging and discharging a battery pack that could be typically found in a hybrid vehicle. Batteries in such packs typically contain strings of cells in series. In a given series of batteries one cell may have a higher or lower state of charge (SOC) than another. This situation leads to a spread of values of state of charge between the various cells.

   When the cells are new this spread of SOCs is quite narrow as all the cells are in substantially the same condition, however as the cells age the spread increases.

   The problem with this is that when the spread gets too large, a charging system may not detect the fact that the cells are fully charged as the average charge of the cells may be below the fully charged threshold.

3. Closest Prior Art

   The closest prior art discloses a system in which the spread of values is accounted for by an iterative system that measures the SOC of each cell and adjusts the threshold for fully charged and discharged accordingly. The problem with this is that the range of movement from fully charged to discharged is continually reduced.

4. Difference between prior art and claims 1, 9 and 17

The present invention seeks to overcome the increase in the spread of SOC values in a series of cell by adopting a preset SOC when the spread of SOC values exceeds a guard value.

5. Technical effect, novelty and inventive step.

The effect of this is to allow accurate determination of SOC and thus to prevent failure discharge and full charge thus allowing the vehicle to make use of the battery and function correctly despite the spread of values of SOC within the pack.

No hint of this particular solution is given in any of the prior art, thus the claims are rendered novel and inventive.

limit value) no longer increases to reach the control center value (FIG. 7B). Then, even though the battery pack is considerably charged, the battery ECU 116 determines that the representative SOC has not increased to the control center value. Therefore, the battery ECU 116 does not output to the HVECU 118 an indication that the SOC has increased to the control center value, and the HVECU 118 does not command the load 120 to stop the charging operation. If this event happens, the charging of the battery pack does not stop but inconveniently continues. In some cases, for the continued charging, the engine cannot be stopped. In some other cases, a hunting phenomenon of repetitive alternation between the charging and the stop thereof may occur. Furthermore, during a run of the vehicle, as it is determined that charging is incomplete despite accomplishment of practically maximum charge, the engine power is consumed for the charging of the battery pack 112 by the generator in addition to the driving of the vehicle by the vehicle-driving motor. Hence, there occurs a case where during a run of the vehicle that requires increased power, for example, an uphill run or the like, sufficient energy cannot be supplied for the driving of the vehicle, thus failing to meet a drivability requirement.

Another method and an apparatus for determining a battery's state of charge is known from US 6,359,419 B1. The method includes determining a current-base state of charge measurement based on coulomb integration, determining a voltage-based state of charge measurement based on the resistance of said battery and a hysteresis voltage, and combining the current-based state of charge measurement and the voltage-based stated of charge measurement to generate the state of charge measurement of the battery.

Further, EP 0 967 108 A1 discloses a battery control apparatus for a hybrid powered vehicle having a voltage detector that detects the voltage levels of battery blocks of a battery set. A presence of an overdischarged cell is detected when a voltage difference between each of the battery blocks reaches or exceeds a predetermined value. At this point, a battery ECU sets the SOC value of the battery set at the lower control limit value. This triggers an HV ECU to control the load such that charging is effectuated in the battery set. If further discharge occurs, the battery set is disconnected from the load by a relay.

EP 0 909 001 A2 also discloses a method and a device for detecting a state of charge of a battery assembly, and a battery assembly charge and discharge control device. Specifically, a variation of the charged amount among battery blocks comprising a battery assembly is detected. By subtracting the detected value of the variation from the width between the upper limit value and the lower limit value of the charged amount, the moveable range of the charged amount is found. The position of the present charged amount is detected as the state of charge. For example, it is arranged that both ends of the movable range are 0% and 100%, and that the movable range is the full scale. Then, the position of the charged amount on this scale is specified by the ratio %. The detection of the state of charge in which the variation in charged amount and the change of the movable range are considered, is performed, and on the basis of this state of charge, a preferable charge and discharge control is performed.

SUMMARY OF THE INVENTION

[0010] The invention has been accomplished in view of the aforementioned problems and the like, and provides battery control apparatus, method and program and a battery control system for a battery pack which are capable of controlling the charge/discharge of the battery pack with improved accuracy despite capacity differences (capacity variation).

[0011] In accordance with an aspect of the invention, a battery pack charge/discharge control apparatus for controlling charge/discharge of a battery pack that is formed by combining a plurality of unit batteries of a secondary battery type, is characterized by comprising: charge/discharge restriction means for restricting the charge/discharge based on at least one of a capacity upper limit value and a capacity lower limit value of the unit batteries constituting the battery pack; remaining capacity detection means for detecting remaining capacities of unit batteries constituting the battery pack; control value computation means for computing a control state-of-charge value based on at least one of a minimum value and a maximum value of the detected remaining capacities; capacity difference computation means for computing, as a capacity difference, a remaining capacity difference between the remaining capacity of a first unit battery and the remaining capacity of a second unit battery among the unit batteries whose remaining capacities have been detected, the remaining capacity of the second unit battery being less than the remaining

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(amended) Claims

1. A battery pack charge/discharge control apparatus for controlling charge/discharge of a battery pack (12) that is formed by combining a plurality of unit batteries (10) of a secondary battery type, comprising:

charge/discharge restriction means (200) for restricting the charge/discharge based on at least one of a capacity upper limit value and a capacity lower limit value of the unit batteries (10) constituting the battery pack (12);

remaining capacity detection means (14, 200) for detecting remaining capacities of unit batteries (10) constituting the battery pack (12);

control value computation means (200) for computing a control state-of-charge value based on at least one of a minimum value (Qmin) and a maximum value (Qmax) of the detected remaining capacities;

capacity difference computation means (200) for computing, as a capacity difference (Qd), a remaining capacity difference between the remaining capacity of a first unit battery and the remaining capacity of a second unit battery among the unit batteries (10) whose remaining capacities have been detected, the remaining capacity of the second unit battery being less than the remaining capacity of the first unit battery;

storage means (200) for storing a correlation between the capacity difference (Qd) and an apparent state-of-charge value (apparent SOC) that is different from the control state-of-charge value (representative SOC);

apparent state-of-charge value computation means (200) for computing an apparent state-of-charge value (apparent SOC) with reference to the correlation based on the capacity difference (Qd); characterized by further comprising:

apparent state-of-charge value adoption means for adopting the apparent state-of-charge value (apparent SOC) if the capacity difference (Qd) is at least a predetermined capacity difference (Q2) that is stored beforehand.

2. The battery pack charge/discharge control apparatus according to claim 1, characterized in that the capacity difference computation means (200) includes maximum remaining capacity detection means for detecting a unit battery (10) having a maximum remaining capacity (Qmax) in the battery pack (12), and minimum remaining capacity detection means for detecting a unit battery (10) having a minimum remaining capacity (Qmin) in the battery pack (12), and computes a remaining capacity difference between the maximum remaining capacity (Qmax) and the minimum remaining capacity (Qmin) as a capacity difference (Qd).

3. The battery pack charge/discharge control apparatus according to any one of claims 1 or 2, characterized by further comprising control state-of-charge value adoption means for adopting the minimum remaining capacity (Qmin) of the unit batteries (10) constituting the battery pack (12) or a percentage of the minimum remaining capacity (Qmin) to a fully charged capacity value (Qfull), as a control state-of-charge value (representative SOC) for controlling the battery pack (12), if the capacity difference (Qd) is less than a pre-stored predetermined capacity difference (Q2).

4. The battery pack charge/discharge control apparatus according to any one of claims 1 through 3, characterized in that if the capacity difference (Qd) is at least a pre-stored predetermined capacity difference maximum value, the predetermined capacity difference maximum value is adopted instead of the capacity difference (Qd).

5. The battery pack charge/discharge control apparatus according to any one of claims 1 through 4, characterized in that the correlation is expressed by Mathematical Expression (1):

$$SOC = \frac{SOCmid - SOClow}{Qhigh - Qlow - Qd} \times (Q\min - Qlow) + SOClow \quad (1)$$

where SOC is the apparent state-of-charge value, and SOCmid is a control center value of the state-of-charge value, and SOClow is a lower limit set value of the state-of-charge value, and SOChigh is an upper limit set value of the state-of-charge value, and Qlow is a capacity value converted from SOClow, and Qhigh is a capacity value converted from SOChigh, and Qd is the capacity difference, and Qmin is the minimum remaining capacity, and Qmax is the maximum remaining capacity.

6. The battery pack charge/discharge control apparatus according to claim 5, characterized in that if in Mathematical Expression (1), the denominator on the right-hand side which is presented as Mathematical Expression (2) is at most a predetermined zero-cross reduction preventative value (Q3), the zero-cross reduction preventative value (Q3) is adopted in place of the denominator expressed by Mathematical Expression (2):

   Qhigh – Qlow – Qd (2)

7. The battery pack charge/discharge control apparatus according to claim 5 or 6, characterized in that if in Mathematical Expression (1), SOC becomes greater than a maximum guard value, the maximum guard value is adopted in place of the term on the left-hand side in Mathematical Expression (1).

8. The battery pack charge/discharge control apparatus according to any one of claims 5 through 7, characterized in that if in Mathematical Expression (1), SOC becomes less than a minimum guard value (MIN guard value), the minimum guard value (MIN guard value) is adopted in place of the term on the left-hand side in Mathematical Expression (1).

9. A battery pack charge/discharge control apparatus for controlling charge/discharge of a battery pack (12) that is formed by combining a plurality of unit batteries (10) of a secondary battery type, comprising:

remaining capacity detector (14, 200) that detects remaining capacities of unit batteries (10) constituting the battery pack (12); and

controller (200) that restricts the charge/discharge based on at least one of a capacity upper limit value and a capacity lower limit value of the unit batteries (10) constituting the battery pack (12),

computes a control state-of-charge value based on at least one of a minimum value (Qmin) and a maximum value (Qmax) of the detected remaining capacities,

computes as a capacity difference (Qd), a remaining capacity difference between the remaining capacity of a first unit battery and the remaining capacity of a second unit battery among the unit batteries (10) whose remaining capacities have been detected, the remaining capacity of the second unit battery being less than the remaining capacity of the first unit battery,

stores a correlation between the capacity difference (Qd) and an apparent state-of-charge value (apparent SOC) that is different from the control state-of-charge value (representative SOC),

computes an apparent state-of-charge value (apparent SOC) with reference to the correlation based on the capacity difference (Qd), characterized in that the controller (200)

adopts the apparent state-of-charge value (apparent SOC) if the capacity difference (Qd) is at least a predetermined capacity difference (Q2) that is stored beforehand.

10. The battery pack charge/discharge control apparatus according to claim 9, characterized in that the controller (200) detects a unit battery (10) having a maximum remaining capacity (Qmax) in the battery pack (12) and a unit

battery (10) having a minimum remaining capacity (Qmin) in the battery pack (12), and computes a remaining capacity difference between the maximum remaining capacity (Qmax) and the minimum remaining capacity (Qmin) as a capacity difference (Qd).

11. The battery pack charge/discharge control apparatus according to any one of claims 9 or 10, characterized in that the controller (200) adopts the minimum remaining capacity (Qmin) of the unit batteries (10) constituting the battery pack (12) or a percentage of the minimum remaining capacity (Qmin) to a fully charged capacity value (Qfull), as a control state-of-charge value (representative SOC) for controlling the battery pack (12), if the capacity difference (Qd) is less than a pre-stored predetermined capacity difference (Q2).

12. The battery pack charge/discharge control apparatus according to any one of claims 9 through 11, characterized in that if the capacity difference (Qd) is at least a pre-stored predetermined capacity difference maximum value, the predetermined capacity difference maximum value is adopted instead of the capacity difference (Qd).

13. The battery pack charge/discharge control apparatus according to any one of claims 9 through 12, characterized in that the correlation is expressed by Mathematical Expression (1):

$$SOC = \frac{SOCmid - SOClow}{Qhigh - Qlow - Qd} \times (Q\min - Qlow) + SOClow \quad (1)$$

where SOC is the apparent state-of-charge value, and SOCmid is a control center value of the state-of-charge value, and SOClow is a lower limit set value of the state-of-charge value, and SOChigh is an upper limit set value of the state-of-charge value, and Qlow is a capacity value converted from SOClow, and Qhigh is a capacity value converted from SOChigh, and Qd is

the capacity difference, and Qmin is the minimum remaining capacity, and Qmax is the maximum remaining capacity.

14. The battery pack charge/discharge control apparatus according to claim 13, characterized in that if in Mathematical Expression (1), the denominator on the right-hand side which is presented as Mathematical Expression (2) is at most a predetermined zero-cross reduction preventative value (Q3), the zero-cross reduction preventative value (Q3) is adopted in place of the denominator expressed by Mathematical Expression (2):
Qhigh – Qlow – Qd (2)

15. The battery pack charge/discharge control apparatus according to claim 13 or 14, characterized in that if in Mathematical Expression (1), SOC becomes greater than a maximum guard value, the maximum guard value is adopted in place of the term on the left-hand side in Mathematical Expression (1).

16. The battery pack charge/discharge control apparatus according to any one of claims 13 through 15, characterized in that if in Mathematical Expression (1), SOC becomes less than a minimum guard value (MIN guard value), the minimum guard value (MIN guard value) is adopted in place of the term on the left-hand side in Mathematical Expression (1).

17. A battery pack charge/discharge control method for controlling charge/discharge of a battery pack that is formed by combining a plurality of unit batteries of a secondary battery type, comprising the following steps of:
restricting the charge/discharge based on at least one of a capacity upper limit value and a capacity lower limit value of the unit batteries (10) constituting the battery pack (12);
detecting remaining capacities of unit batteries (10) constituting the battery pack (12);

computing a control state-of-charge value based on at least one of a minimum value (Qmin) and a maximum value (Qmax) of the detected remaining capacities;

computing, as a capacity difference (Qd), a remaining capacity difference between the remaining capacity of a first unit battery and the remaining capacity of a second unit battery among the unit batteries (10) whose remaining capacities have been detected, the remaining capacity of the second unit battery being less than the remaining capacity of the first unit battery;

storing a correlation between the capacity difference (Qd) and an apparent state-of-charge value (apparent SOC) that is a state-of-charge value different from the control state-of-charge value (representative SOC);

computing an apparent state-of-charge value (apparent SOC) with reference to the correlation based on the capacity difference (Qd); characterized by comprising the further step:

adopting an apparent state-of-charge value (apparent SOC) if the capacity difference (Qd) is at least a predetermined capacity difference (Q2) that is stored beforehand.

18. A battery pack charge/discharge control program that is read into a computer so as to control charge/discharge of a battery pack that is formed by combining a plurality of unit batteries of a secondary battery type, characterized by comprising:

restricting the charge/discharge based on at least one of a capacity upper limit value and a capacity lower limit value of the unit batteries (10) constituting the battery pack (12);

detecting remaining capacities of unit batteries (10) constituting the battery pack (12);

computing a control state-of-charge value (representative SOC) based on at least one of a minimum value (Qmin) and a maximum value (Qmax) of the detected remaining capacities;

computing, as a capacity difference (Qd), a remaining capacity difference between the remaining capacity of a first unit battery and the remaining capacity of a second unit battery among the unit batteries (10) whose remaining capacities have been detected, the remaining capacity of the second unit battery being less than the remaining capacity of the first unit battery; and

computing an apparent state-of-charge value (apparent SOC) that is different from the control state-of-charge value (representative SOC), with reference to a correlation between the capacity difference (Qd) and the apparent state-of-charge value (apparent SOC).